भारतीय मानक
Indian Standard

IS 11485 : 2014
(Reaffirmed 2020)

कंक्रीट और चिनाई बाँधों के स्लूइसों के डिजाइन के लिए मापदंड

(पहला पुनरीक्षण)

Criteria for Design of Sluices in Concrete and Masonry Dams

(First Revision)

ICS 17.120.20

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Dams and Spillways Sectional Committee, WRD 09

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Dams and Spillways Sectional Committee had been approved by the Water Resources Division Council.

Sluices are provided in the body of the dam to release regulated supplies of water for a variety of purposes which are briefly listed below.

a) River diversion;

b) Irrigation;

c) Generation of hydro-electric power;

d) Water supply for municipal or industrial uses;

e) To pass the flood discharge in conjunction with the spillway;

f) Flood control regulation to release water temporarily stored in flood control storage space or to evacuate the storage in anticipation of flood inflows;

g) Depletion of the reservoir in order to facilitate inspection of the reservoir rim and the upstream face of the dam and for carrying out remedial measures, if necessary;

h) To furnish necessary flows for satisfying prior right uses downstream; and

j) For maintenance of a live stream for abatement of stream pollution, and preservation of aquatic life.

The flow through a sluice may be either pressure flow or free flow along its entire length or a combination of pressure flow in part length and free flow in the remaining length.

This standard was first published in 1985. This revision has been taken up to incorporate structural design aspect of sluices in concrete and masonry dams, to make the standard comprehensive.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

CRITERIA FOR DESIGN OF SLUICES IN CONCRETE AND MASONRY DAMS

(First Revision)

1 SCOPE

1.1 This standard lays down the criteria for hydraulic and structural design of sluices provided in concrete and masonry dams for the purpose of conveying water from reservoir to down-stream either during construction period or during operation period.

1.2 The design of sluices which are large in comparison with the size of the dam is not included in the scope of this standard.

NOTE — Sluice is considered large when either of the following is complied with,

a) If $d > 7$ m, where d is maximum cross-sectional dimension;

b) If $A > 50$ m^2, where A is area of cross-section of sluice; or

c) Concrete or masonry cover any where around it is less than d.

1.3 This standard does not cover the design of openings for penstocks.

2 REFERENCES

The following standards contain provision which, through reference in this text constitute provisions of this standard. At the time of publication the edition indicated was valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standard indicated below.

IS No.	*Title*
456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
1786 : 2008	Specification for high strength deformed steel bars and wires for concrete reinforcement (*fourth revision*)
6512 : 1984	Criteria for design of solid gravity dams (*first revision*)
8605 : 1977	Code of practice for construction of masonry in dams
12966 (Part 2) : 1990	Code of practice for galleries and other openings in dams Part 2 Structural designs

3 TYPES OF SLUICES

3.1 Straight Barrel Sluice

The barrel of this sluice is kept nearly horizontal between the entry and exit transitions (*see* Fig. 1A,1B and1C). This sluice has the advantage of having minimum length due to which lesser friction losses take place.

3.1.1 Horizontal sluices are generally used under the following conditions:

a) When the sluices are drowned at the exit; and

b) When they have to be located at or near the river bed level, for example in sluices for river diversion or reservoir depletion.

3.1.1.1 The width of the sluice barrel is generally kept uniform throughout the length except in the entry transition.

3.1.1.2 If the sluice is designed for pressure flow conditions then the top profile of the sluice may be given a slight constriction in accordance with **4.4.1**. On the other hand if free flow conditions prevail then no such constriction is required.

3.2 Trajectory Type Sluice

The barrel of this sluice is generally kept horizontal downstream of the entry transition up to the service gate to facilitate resting of the latter. Beyond the service gate the bottom of the sluice conforms to the parabolic path of the trajectory and meets the downstream face of the dam section tangentially (*see* Fig. 1D and 1E).

3.2.1 The equation of the bottom profile after the service gate shall be:

$$x^2 = k.H.y$$

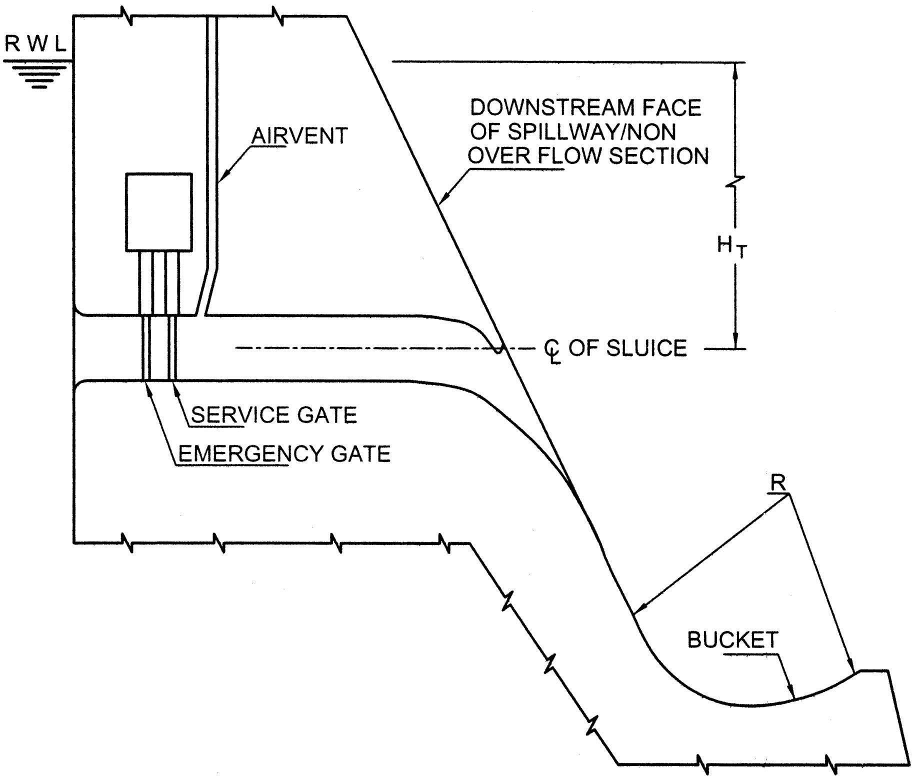
where

k = coefficient (A value of about 4 is generally used depending on the distance available to accommodate this curve in the reach between the service gate and the downstream face of the spillway/non-overflow section),

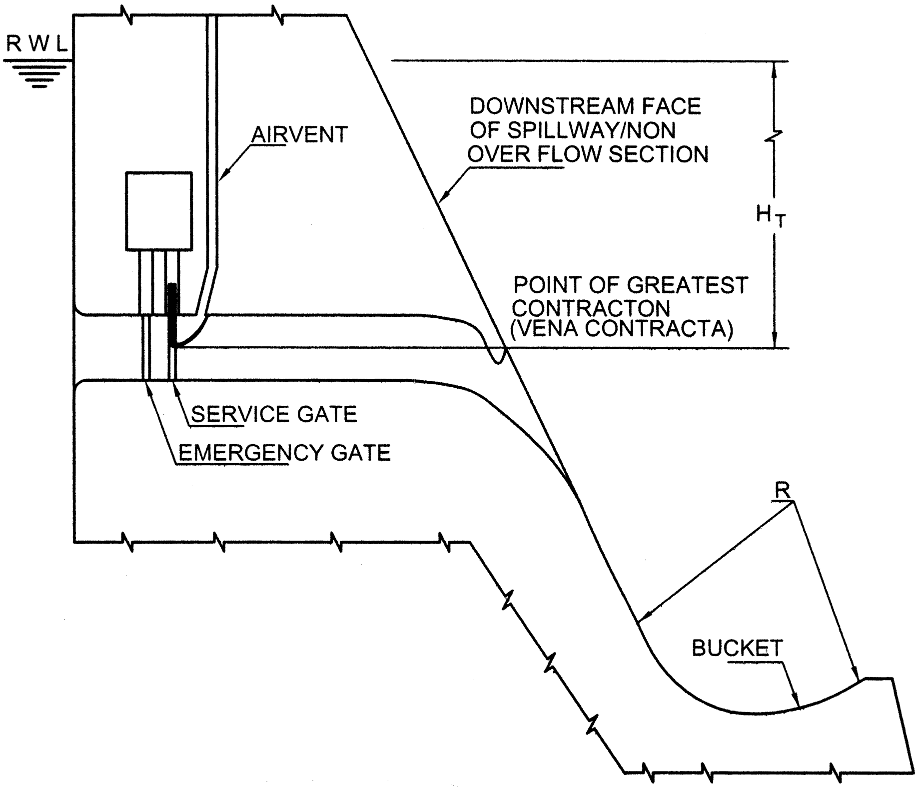
H = head at the center line of the gate opening, and

x, y = co-ordinates of any point on the profile (*see* Fig. 1D, 1E).

In case the trajectory profile of sluice would not permit meeting tangentially the downstream face of dam, a small transition just before the tangent point (TP) of sluice profile and downstream face of dam in form of

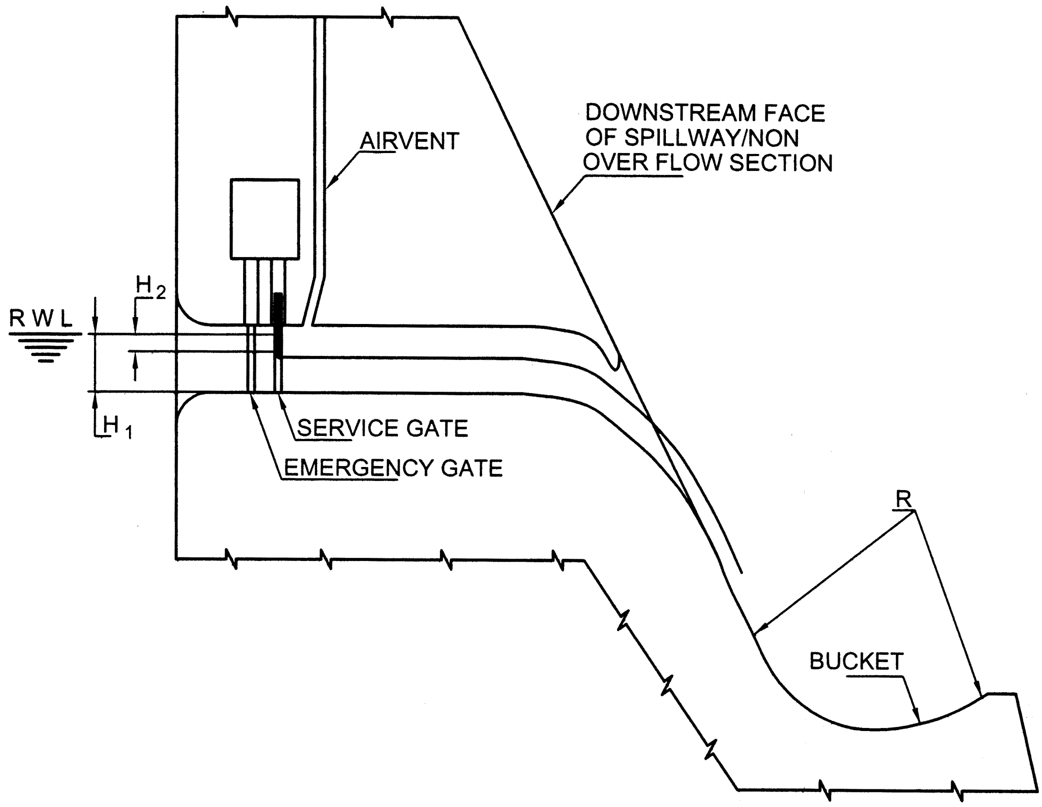


1A Straight Barrel Sluice

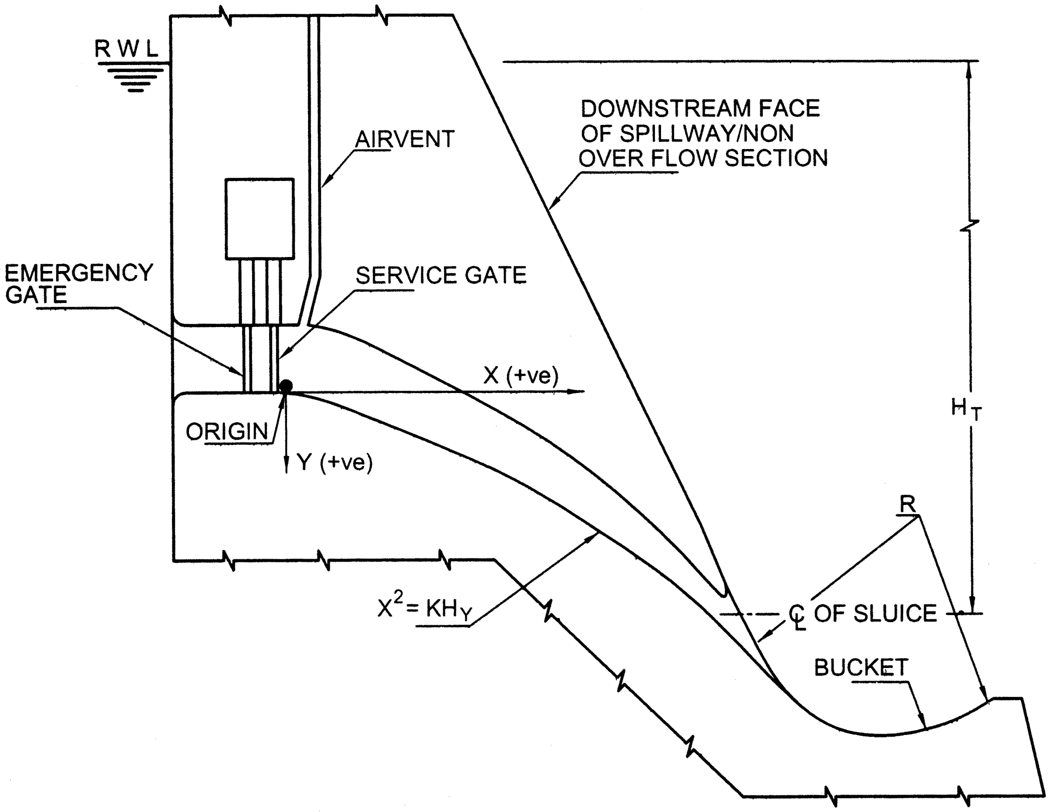


1B Straight Barrel Sluice with Partial Gate Opening with Free Flow

FIG. 1 TYPE OF SLUICE (*Continued*)

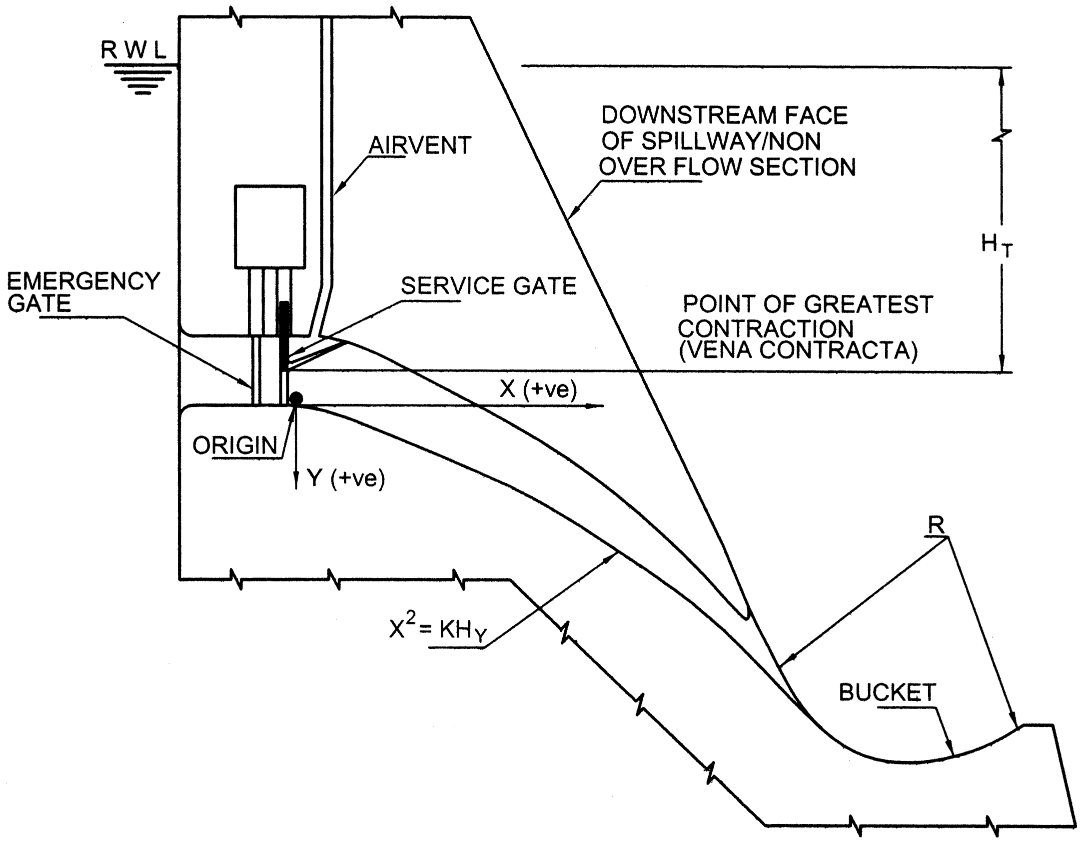


1C Straight Barrel Sluice with Partial Gate Opening



1D Trajectory Type Sluice

FIG. 1 TYPE OF SLUICE (*Continued*)



1E Trajectory Type Sluice with Partial Gate Opening

FIG. 1 TYPE OF SLUICE

vertical curve with suitable radius of curvature may be provided.

3.2.2 The width of the sluice is kept uniform through out the length except in the entry transition.

3.2.3 The height of the sluice is gradually reduced from downstream of the service gate to the exit in order to ensure pressure flow in the sluice. The constriction shall be in accordance with **4.4.1**.

4 HYDRAULIC DESIGN CONSIDERATIONS

4.1 Fixation of Size and Number of Sluices

The size and number of sluices required to pass the desired discharge at a predetermined reservoir elevation may be found based on the type of flow required to be maintained in the sluice, that is, either pressure flow or free flow or a combination of both. The sluice dimensions shall be so proportioned as to provide a preferably atleast two number of sluices to permit inspection and repair of the same.

4.1.1 *Pressure Flow in the Sluice*

For pressure flow conditions, the following basic relation may be used:

$$H_T = h_L + h_v$$

where

H_T = total head needed to overcome various head losses to produce discharge,

h_L = the cumulative losses of the system in terms of velocity head, and

h_v = velocity head at the flow control that is at the sluice exit.

For a free discharging sluice H_T shall be measured from the reservoir water surface to the center of the sluice at the exit (*see* Fig. 1A, 1B and 1D). If the out flowing jet is supported on a downstream floor the head shall be measured to the point of flow control (*see* Fig. 1B and 1E) that is at the exit and if the sluice is submerged at the exit then the head shall be measured to the tail water level. The losses shall consist of trashrack losses, entrance losses, exit losses, friction losses, gate or valve losses, bend losses, gate groove losses, expansion, contraction losses etc. They may be expressed in terms of velocity head. The above equation may be re-written in a simplified form as follows:

$$H_T = K_L \frac{V^2}{2g}$$

Then $Q = a_x \sqrt{\dfrac{2gH_T}{K_L}}$

K_L = constant, which is obtained after considering all the losses in the system;

V = velocity at the point of flow control where the cross-sectional area is a_x;

a_x = cross-sectional area of the sluice, where the control of flow exists;

g = acceleration due to gravity; and

Q = discharge to be passed through the sluice at a predetermined reservoir elevation.

4.1.2 *Free Flow (Open Channel Flow) in the Sluice*

4.1.2.1 When open channel flow is controlled by regulating gates (*see* Fig 1C), the following relation shall be used:

$$Q = \frac{2}{3} C.B\sqrt{2g}\,(H_1^{3/2} - H_2^{3/2})$$

where

Q = discharge to be passed through sluice;

g = acceleration due to gravity;

B = width of the sluice;

H_1, H_2 = head upto the sill of sluice and bottom of lifted gate respectively under its lifting condition subjected to any F.R.L/ R.W.L (*see* Fig. 1C); and

C = coefficient of discharge (*see* Table 1).

Table 1 Coefficient of Discharge, *C* for Conduit Entrances

(*Clause* 4.1.2.1)

Particulars	Coefficient of Discharge *C*		
	Maximum	Minimum	Average
Gate in thin wall – unsuppressed contraction	0.70	0.60	0.63
Gate in thin wall – bottom and sides suppressed	0.81	0.68	0.70
Gate in thin wall – corners rounded	0.95	0.71	0.82

4.1.2.2 When there is high tail water either due to canal water supply level or downstream influence in the stream bed, the regulating gate opening may be either partly or entirely submerged. For the unsubmerged part of the gate opening the discharge shall be calculated according to **4.1.2.1**. However, for the submerged part of the gate opening discharge shall be calculated by the following relation:

$$Q = C.A.\sqrt{2gH}$$

where

Q = discharge through submerged portion of the gate opening

A = area of the submerged portion of the sluice;

H = difference between upstream and down stream water levels, and

C = coefficient of discharge for submerged orifice or tube flow. (Its value generally varies between 0.62 to 0.81)

4.1.3 For calculating the size of the sluice and plotting the water surface profile maximum losses shall be considered. However, minimum losses shall be considered for the design of the energy dissipation arrangements for the flow through sluices.

4.2 Shape of Sluice

Generally rectangular gates are preferred. Therefore, the shape of sluices is also normally kept rectangular. Generally the height of the sluice is kept as 1.5 times the width. However, circular shapes may also be provided when small diameter openings (less than 1m) are required to be regulated by valves.

4.3 Entry Transitions

The efficient functioning of a sluice depends to a great extent on the design of its entry transitions. To obtain the best inlet efficiency, the shape of the entrance shall simulate that of a jet discharging into air. A bell mouth entrance which conforms to or slightly encroaches upon the free jet profile will provide the best entrance shape. Elliptical entrances have been found to be suitable.

4.3.1 For a rectangular or square sluice the entrance transition may be defined by the following equation:

$$\frac{x^2}{D^2} + \frac{y^2}{(0.33D)^2} = 1$$

where D is the vertical height of the sluice (downstream of the entrance curve) for top and bottom curves and the horizontal width of the sluice (downstream of the entrance curve) for the side curves.

4.3.2 For a rectangular entrance with bottom placed even with upstream floor, the side curves at the entrance may be defined by the above equation. However, the top contraction curve may be given by the following equation:

$$\frac{x^2}{D^2} + \frac{y^2}{(0.67D)^2} = 1$$

where D is the vertical height of the sluice downstream of the entrance transition.

4.3.3 For a circular entrance the entry transition is given the following equation:

$$\frac{x^2}{(0.5D)^2} + \frac{y^2}{(0.15D)^2} = 1$$

where D is the diameter of the sluice downstream of the entrance transition.

4.4 Exit of the Sluice

The exit of the sluice shall be tangential to either the downstream face of the spillway non-overflow section or the bucket or it may be upturned (*see* Fig. 2).

4.4.1 In order to ensure the pressure flow conditions through out the length of the sluice and to avoid negative pressures the section of the sluice shall be constricted at the exit so as to give reduced cross-sectional area to commensurate with the increase in the velocity of flow. A constriction of 10 to 15 percent in flow area is generally found adequate by effective constriction in the roof profile only.

4.4.2 When the exit of the sluices is not drowned, the top profile of the sluices is given a small turn of about 1.0 to 1.5 m normal to the downstream face of the spillway/non-overflow section. This helps in the aeration of the sluice (*see* Fig. 2).

4.4.3 In case of an upturned exit, the shape and dimensions of the profile may be best worked out on the basis of the model studies. It has to be used with caution, because the flow from the sluice may damage the energy dissipation arrangements of the spillway or the downstream face of the spillway/non-overflow section if it falls over them. Alternatively, a jet disperser of suitable shape, based on model studies may be provided.

4.4.4 In case of the sluices located in spillway then no separate energy dissipation arrangements are necessary. However, if they are provided in a non-overflow section, then separate energy dissipation arrangements may have to be provided.

4.4.5 In case the spillway and sluice run together then either eyebrow deflectors may be provided on the exit of the sluice or aeration be provided at the exit end.

4.5 Control Devices

The flow through sluices is controlled by either gates or valves. Generally, two sets of gates, that is, emergency and services gates are provided. In case of construction sluices, the flow is generally uncontrolled and only stoplogs are provided for the eventual plugging of the sluices. Where the construction sluices are required to be closed under flowing water, provision of emergency gates may be considered.

4.5.1 The control (services) gates shall be located as far upstream as possible. The operation and servicing may be done from operation galleries/chambers in the dam (*see* Fig. 3). In order to repair the gates without emptying the reservoir, the usual practice is to install a guard or emergency gate, further upstream in the sluices. These emergency gates may be placed either at the entrance or inside the sluice and operated from galleries.

4.5.2 Sometimes when the sluice have to be located at high levels near the crest in the spillway section, where it is not possible to provide a gallery for gates operation, the sluices may also be located in thick spillway piers in which the gates are operated from the top of the pier (*see* Fig. 4).

4.5.3 In case of high heads (more than 30 m) gate controls may also be located near the downstream end of the sluice to minimize possibilities of cavitation.

4.5.4 For better slot hydraulics, the gate slots shall be as small as practicable and adequately streamlined.

4.6 Air Vents

Air vents of suitable size shall be provided downstream of the control gates to supply air and thereby avoid or minimize cavitation damages. The air demand for calculating the size of air vent may be calculated from the following formulae:

a) For hydraulic jump formation in the conduit

$$\beta = 0.006\,6\,(F_{1c} - 1)^{1.4}$$

b) For spray flow

$$\beta = 0.20\,F_{1c}$$

c) For free flow

$$\beta = 0.09\,F_{1c}$$

where

β = air-demand ratio = $\dfrac{\text{Volume flow rate of air}}{\text{Volume flow rate of water}}$

F_{1c} = Froude number at Vena contracta

$= \dfrac{V_{1c}}{\sqrt{g d_{1c}}}$

V_{1c} = velocity of flow at the vena contracta,

d_{1c} = depth of flow at the vena contracta, and

g = acceleration due to gravity.

The size of air vents as determined above assumes that the maximum air demand occurs at a gate opening of 80 percent open and the maximum air velocity in the vent does not exceed 50 m/s. Air vent passages shall use generous bend radii and gradual transitions to avoid losses and particularly excessive noise. The air vent intakes should be so located that they are inaccessible to the public and shall be protected by grills. The intake entrance average velocity shall not exceed 10 m/s. The

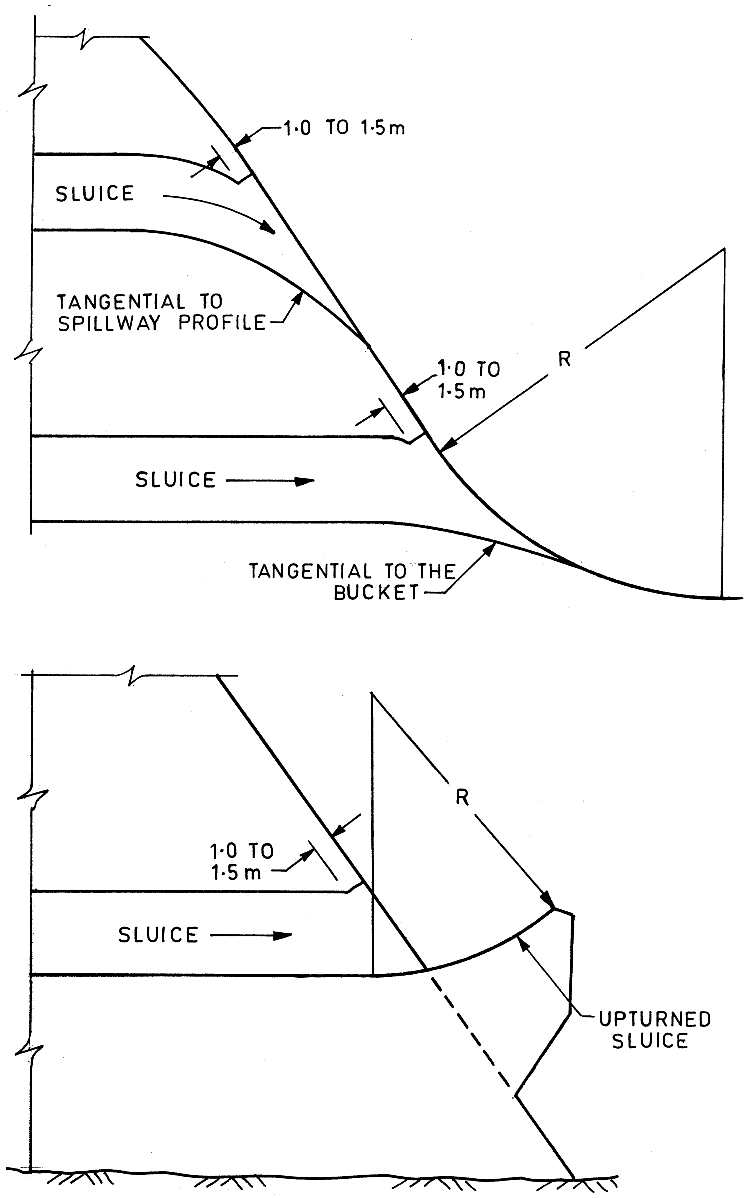


FIG. 2 TYPES OF SLUICE EXIT

air vent exit portal shall be designed to ensure spread of air across the full width of the conduit. The air vent shall terminate into a plenum located in the conduit roof and immediately downstream of the gate. The plenum shall extend across the full width of the conduit and shall be vaned so that the air flow is evenly distributed.

4.6.1 The size of the air vent shall be such that the pressure drop downstream of the gate does not normally exceed 2 m.

4.6.2 Hydraulic jump formation in the sluice shall normally be avoided. When unavoidable sufficient clearance shall be provided above the jump profile to avoid choked jump conditions.

4.6.3 Normally a sluice located in a spillway section shall not operate simultaneously with the spillway. However, if it is obligatory to run the sluice in conjunction with the spillway, proper aeration shall be ensured at the exit either by running the sluice partially full or by providing a suitable air-vent at the exit of the sluice.

4.6.4 Sometimes a steel liner may also be provided in the sluices near the gates to avoid cavitation damages. In case of control being located at the exit end, the entire length of sluice shall be provided with steel liner.

4.7 Model Studies

Hydraulic model studies are desirable to test the efficacy of the hydraulic design of the sluice and to verify the air-demand. They shall be done for the pre-determined minimum reservoir elevation at which the sluice is designed to pass the required discharge and

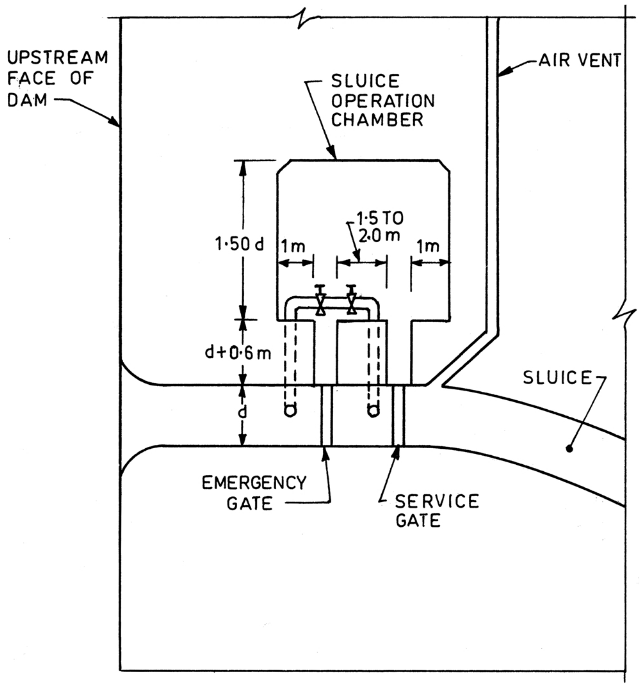


FIG. 3 A TYPICAL ARRANGEMENT WITH GATES OPERATION FROM OPERATION CHAMBER
(DETAILS OF GATES AND HOISTS NOT SHOWN)

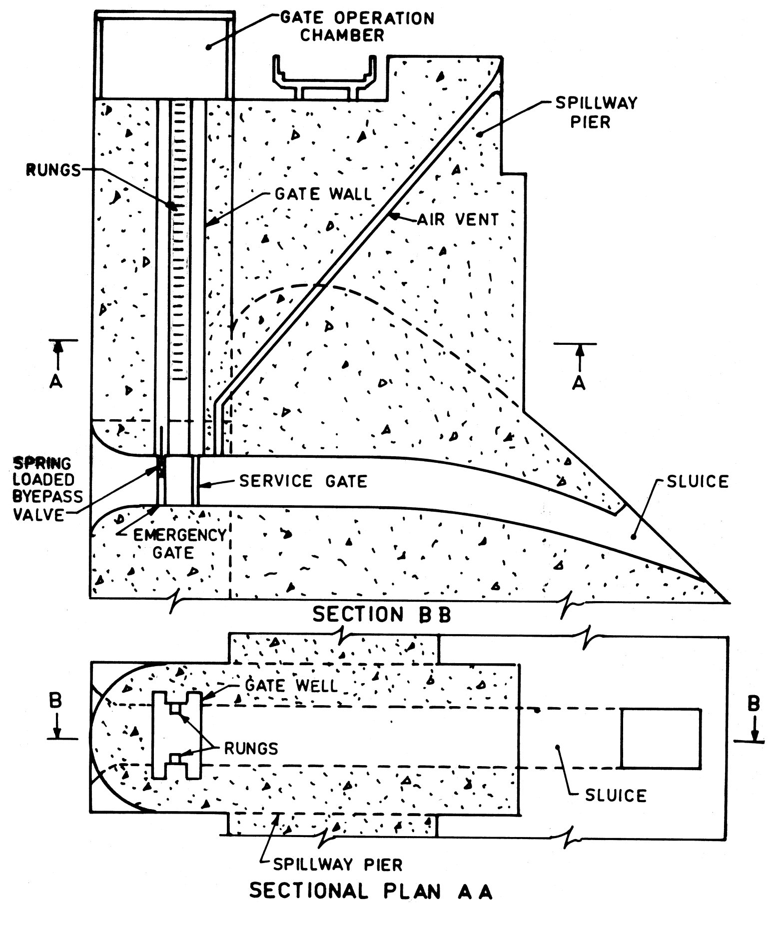


FIG. 4 TYPICAL DETAILS OF SLUICE LOCATED IN THICK SPILLWAY PIER

also for higher reservoir elevations under the gate opening necessary to pass the same discharge.

5 STRUCTURAL DESIGN CONSIDERATIONS

5.1 Design Assumptions

5.1.1 The grade of concrete used around the sluice shall conform to IS 456 and have minimum cube strength of 20 N/mm^2 and a minimum thickness of 1 m.

5.1.1.1 The reinforcement used shall be high strength deformed bars conforming to IS 1786.

5.1.1.2 The problem is treated as plane stress problem.

5.1.1.3 Concrete is assumed to behave as an elastic material.

5.1.1.4 Tensile force is taken only by steel reinforcement.

5.1.2 *Permissible Stresses*

The permissible stresses in concrete shall be in accordance with IS 456. The permissible stress in reinforcement shall be taken as 80 percent of the values specified in IS 456, while for masonry, it shall be in accordance with IS 6512. For reinforcement, however, a permissible stress of 190 N/mm^2 and 230 N/mm^2 be adopted for high strength deformed bars of grade Fe 415 and Fe 500 respectively conforming to IS 1786.

5.1.3 *Increase in Permissible Stresses*

The permissible stresses mentioned in **5.1.2** shall be increased by $33\frac{1}{3}$ percent when earthquake loads are considered in the design.

5.2 Loads to be Considered in the Analysis

The following loads shall be considered in the structural design of the sluice barrel:

a) Dead load of the structure;
b) Reservoir and tail water loads;
c) Earthquake loads;
d) Uplift pressure;
e) Internal water pressures (hoop tension);
f) Earth and silt pressure;
g) Ice pressure;
h) Wind and wave pressure;
j) Loads due to road bridge;
k) Loads due to gates, hoisting equipments etc; and
m) Temperature stresses.

5.3 Analysis

5.3.1 Openings in the structure develop a discontinuity in the stress field and due to stress concentration around the openings, zones of high compressive stresses or tensile stresses may develop and in general this will weaken the structure. Reinforcement requires to be provided around the openings to avoid the uncontrolled cracking of concrete.

5.3.2 The stress field at the center of the opening can be determined by any of the following methods.

5.3.2.1 *Gravity method of analysis*

This analysis assumes a linear distribution of vertical stresses on horizontal planes. This method provides a two dimensional solution and idealizes the dam as composed of number of vertical cantilevers and assumes that each cantilever carries the loads to the foundation without any transfer of the loads to adjacent vertical elements. The shear stress distribution is assumed as parabolic and the horizontal stress distribution as cubic. For details reference may be made to IS 12966 (Part 2).

5.3.2.2 *Photoelastic method*

This can be an experimental method of stress analysis using models made of birefringent materials. Observation of loaded model under polarized light shows fringe patterns. The complete stress distribution in a plane structure, can be determined using fringe pattern and other supplementary data.

5.3.2.3 *Finite element method (FEM)*

In this method, the structure is conceptually divided into a number of elements and the stiffness of each element is determined. The load and the displacement conditions of each element are introduced and the simultaneous equations of equilibrium in terms of displacements are obtained there from and are solved using computer. Finally, the computation of the stresses is made using the displacement data.

5.3.3 *Stress Distribution Around Opening*

The stress distribution around the opening at any location may be determined by theory of elasticity, stress coefficients method, photoelastic method or finite element method.

5.3.4 *Load Combinations*

Different loads to be considered in the design are mentioned in **5.3**. Design shall be based on the adverse combinations of loads which lead to the development of critical stresses. They shall include those loads having a reasonable probability of occurring at the same time. The different loading conditions are listed in IS 6512.

5.3.4.1 *Reinforcement Design*

The grade of concrete used around the sluice shall

conform to IS 456 and have a minimum cube strength of 20 N/mm^2 and a minimum thickness of 1 m.

In case of masonry dams the portion around an opening which is reinforced is constructed in concrete and the minimum thickness of concrete shall be 1 m.

5.3.4.2 The reinforcement provided shall be adequate for withstanding the total tensile stresses due to (a) stress concentration, (b) internal water pressure, and (c) temperature stresses.

5.3.5 *Reinforcement for Stress Concentration*

a) Reinforcement for stress concentration (for critical combination of loadings) is determined by the following steps:

1) Locate the center of the opening on dam cross-section.
2) Determine the prevalent stress field at that location in the absence of opening.
3) Determine the stress distribution around the opening subjected to uniform stress field arrived at **5.3.5** (a)(2) [*see* Fig. 3 and Fig. 4 of IS 12966 (Part 2)].
4) Compute the total tensile force across the section.
5) Compute the area of steel required.

b) *Location of critical section computation of total tension*

The critical section is determined on the basis of maximum tensile stress and maximum total tension. To determine this, it is necessary to obtain normal stress distribution along various reference lines, analytically or experimentally. The total tension is determined by integrating the area under tension along the particular critical section.

c) *Area of steel reinforcement*

After obtaining the total tension for critical section for the opening, the area of steel A_{st} is calculated as F/σ_{st}

d) *Detailing of reinforcement*

Typical reinforcement details are shown in Fig. 5. The bars shall be straight as far as possible and anchored in the zone of compressive stress. Diagonal bars shall be provided at the corners, and fillets. The minimum diameter of reinforcement bar shall be 16 mm and the maximum spacing shall be 300 mm c/c. The minimum cover shall not be less than 150 mm.

5.3.6 *Reinforcement for Internal Water Pressure*

The reinforcement for internal water pressure is determined as follows (*see* Fig. 6):

Let *W* and *H* be the width and height of the sluice.

'*P*' is the internal water pressure

(acting at the center of the section)

Area of reinforcement steel for faces AD and BC

$$= \frac{PH}{2\sigma_{st}}$$

Area of reinforcement steel for faces AB and CD

$$= \frac{PW}{2\sigma_{st}}$$

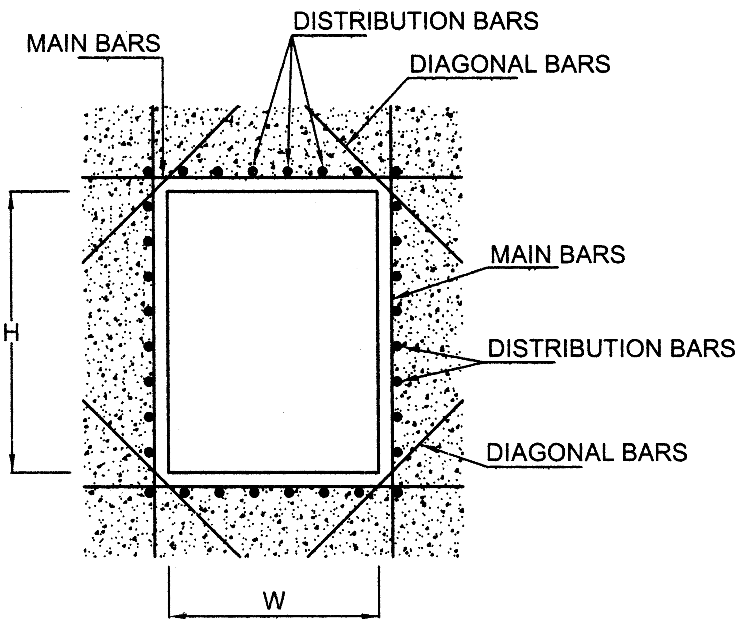


FIG. 5 TYPICAL REINFORCEMENT DETAILS AROUND A SLUICE

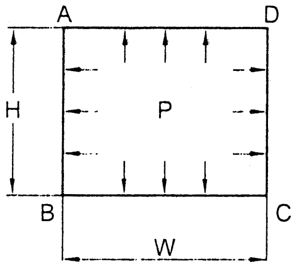


FIG. 6 INTERNAL WATER PRESSURE

5.3.7 *Reinforcement for Temperature Stresses*

When the control gate of sluice is opened during the construction period or operating period, water at lower temperature gushes into the sluice. The inner periphery of the sluice thus attains a lower temperature than the concrete around it. The temperature gradient around the sluice induces thermal stresses which are tensile in nature and around the inner periphery of the sluice.

The thermal stresses are computed based on the theory of thick cylinders subjected to thermal gradients. The thickness of structural concrete around the opening is taken into account to compute the inner and outer radius. The rectangular opening area is transformed to equivalent circular area.

$$\text{Internal Radius } R_1 = \sqrt{\frac{W\ H}{\pi}}$$

$$\text{External Radius } R_2 = \sqrt{\frac{(W + 2T)(H + 2T)}{\pi}}$$

where

T = thickness of structural concrete around the opening.

Circumferential tension on the inner surface:

$$\sigma_{R_1} = \frac{-E\alpha(\theta_1 - \theta_m)}{1-\nu}$$

θ = temperature at a distance R from the center of the circle.

Assuming a linear variation of temperature from the inner to outer periphery (*see* Fig. 7)

$$\theta = \frac{R - R_1}{R_2 - R_1}(\theta_2 - \theta_1) + \theta_1$$

$$\text{Hence } \theta_m = \frac{2}{R_2^2 - R_1^2}\int_{R_1}^{R_2} \theta R dR$$

$$\text{Or } \quad \theta_m = \frac{2}{R_2^2 - R_1^2}\int_{R_1}^{R_2}\left[\frac{R - R_1}{R_2 - R_1}(\theta_2 - \theta_1) + \theta_1\right] R dR$$

Integrating

$$\theta_m = \theta_1 + \frac{(\theta_2 - \theta_1)\left(2R_2^3 - 3R_1R_2^2 + R_1^3\right)}{3\left(R_2^2 - R_1^2\right)\left(R_2 - R_1\right)}$$

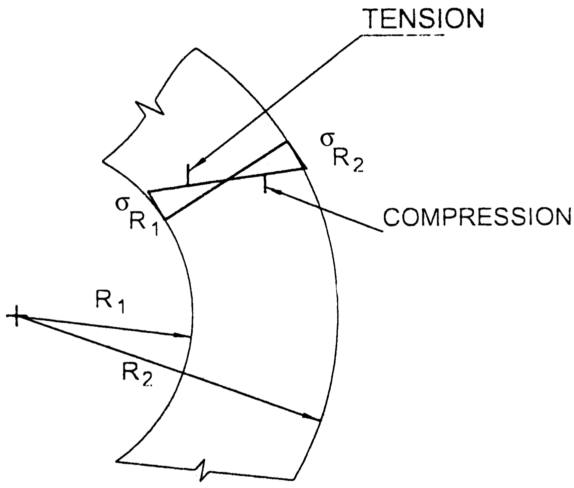


FIG. 7 TEMPERATURE VARIATIONS

Circumferential compression at the outer radius is given by

$$\sigma_{R_2} = \frac{-E\alpha(\theta_2 - \theta_m)}{1-\nu}$$

Knowing σ_{R_1} and σ_{R_2} total tensile force can be found out and area of reinforcement steel computed for the same.

NOTE — FEM analysis for this case does not involve approximation like transformation of rectangular opening to equivalent circular area.

5.3.7.1 *Special cases*

a) *Opening close to the block joint*

The sluice opening may be kept at least at a distance *d* away from the block joint. When the sluice opening is provided close to the block joint, photoelastic methods or finite element method may be used to obtain the stress fields.

b) *Multiple openings*

When more than one sluice opening is provided in the same dam block, the minimum clear spacing between these openings shall be equal to the width of the opening. The compressive stresses due to stress concentration shall be within the allowable limits. Otherwise reinforcements for compression shall be provided wherever required.

Further, in addition to loading conditions enumerated in **5.3.4** other condition arising due to one sluice running full under pressure while the adjacent one empty is, shall also be considered (where the minimum spacing of one width is provided).

c) For openings considered as large (*see* note under **1.2**) and closely spaced openings detailed two or three dimensional analysis shall be carried out either by Finite element method or photo elastic method.

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